Space Weather Technical Forecast

Issued on Thursday, 23 November 2023 at 13:40 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: R1-R2 Radio Blackouts likely throughout. Chance of G1 Geomagnetic Storms, day 3-4 (25-26 Nov).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate with the largest flare an M1.4 event at 23/0338 UTC. This is from an uncertain source given simultaneous flaring from a number of regions at the time, but is either from AR3492, AR3494 or a new region at the northeast limb. There are currently thirteen sunspot groups on the visible disc, the majority of which are located in the eastern solar hemisphere. The largest group is a new, magnetically complex region in the far southeast. The northeast of the disc contains a cluster of moderately large sunspot groups that appear to be magnetically connected. Of these, AR3490 continues to show the presence of a small delta spot in the southern portion of the group. Meanwhile, the previous small delta spot in AR3492 appears to have decayed.

One potential Earth-directed CME has been observed in the past 24 hours. A partial halo CME is evident in LASCO and STEREO imagery from 22/2100 UTC onwards, directed mainly southwards. A coronal dimming spanning several hours is apparent starting around 22/1930 UTC in the vicinity of AR3489. This is also accompanied by two flare ribbons, indicative of post-eruptive magnetic reconnections in the Sun's corona following a filament eruption. Confidence is moderate for a CME arrival at Earth from this around 26/0000 UTC.

Solar Wind / Geomagnetic Activity: Solar wind parameters, as measured by ACE and DSCOVR at L1, have been indicative of a waning connection to CH73/+. Wind speeds have fallen from 570km/s to 450km/s. The solar density was generally below or around average. The IMF has erratically fallen from a maximum of 9nT down to around 3-4nT. The important north-south component (Bz) has varied weakly, between +7/-7nT, though largely favoured a southward direction. Phi angle was mainly positive (away from the Sun). Resultant geomagnetic activity was Unsettled to Active (Kp3-4) initially, but eased to become Quiet (Kp1-2) by the end of the 24 hour period.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux remained at Background levels. GOES16 high energy (greater than 2MeV) electron flux increased from background to Moderate levels, peaking at 504pfu at 23/1200 UTC. The associated 24-hour fluence has remained below the Active threshold (1e8 integrated pfu), but on a steadily increasing trend. The fluence observation at 23/0000 UTC was 3.33e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Moderate with further isolated M-class flares (R1-R2, Minor-Moderate) likely and a slight chance of isolated X-class (R3-Strong) flares, mainly from current eastern solar hemisphere sunspot regions.

Solar Wind / Geomagnetic Activity: Two Earth-directed CMEs have been analysed and modelled, likely arriving at Earth day 1-2 (24-25 Nov) and day 2-3 (25-26 Nov).

Earth remains connected to the waning HSS of coronal hole CH73/+. Slightly elevated solar winds should ease back to background levels in the next couple of days. No further coronal hole

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enhancements are expected until the arrival of CH75/+ later on day 3 (25 Nov) or more likely day 4 (26 Nov), with speeds of up to 500-550 km/s possible.

Geomagnetic Activity will be mainly Quiet on day 1 and 2 (23 and 24 Nov), with a chance of isolated Unsettled intervals. Activity should then increase to Active to G1/Minor Storm levels with the arrival of the first CME. This is most likely to occur early on day 3 (25 Nov), but with a slight chance of occurring late day 2 (24 Nov). Activity may briefly ease to Unsettled, then increase once again to mainly Active to G1/Minor Storm levels later day 3 (25 Nov) into day 4 (26 Nov) given combined HSS and further expected CME influences.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is expected to remain at Background levels. GOES16 Electron flux levels are expected to continue to increase in the next couple of days as the current solar wind pressure from a coronal hole continues to ease. Flux levels should increase to vary between Moderate and diurnally High levels. A suppression of electron flux to mainly background levels is expected towards the end of the period due to combined CME and HSS influences. Fluence levels are expected to remain below the 1e8 Active threshold initially, the risk of this being breached increases from day 2 (24 Nov) into day 3 (25 Nov), before decreasing again into day 4 (26 Nov).

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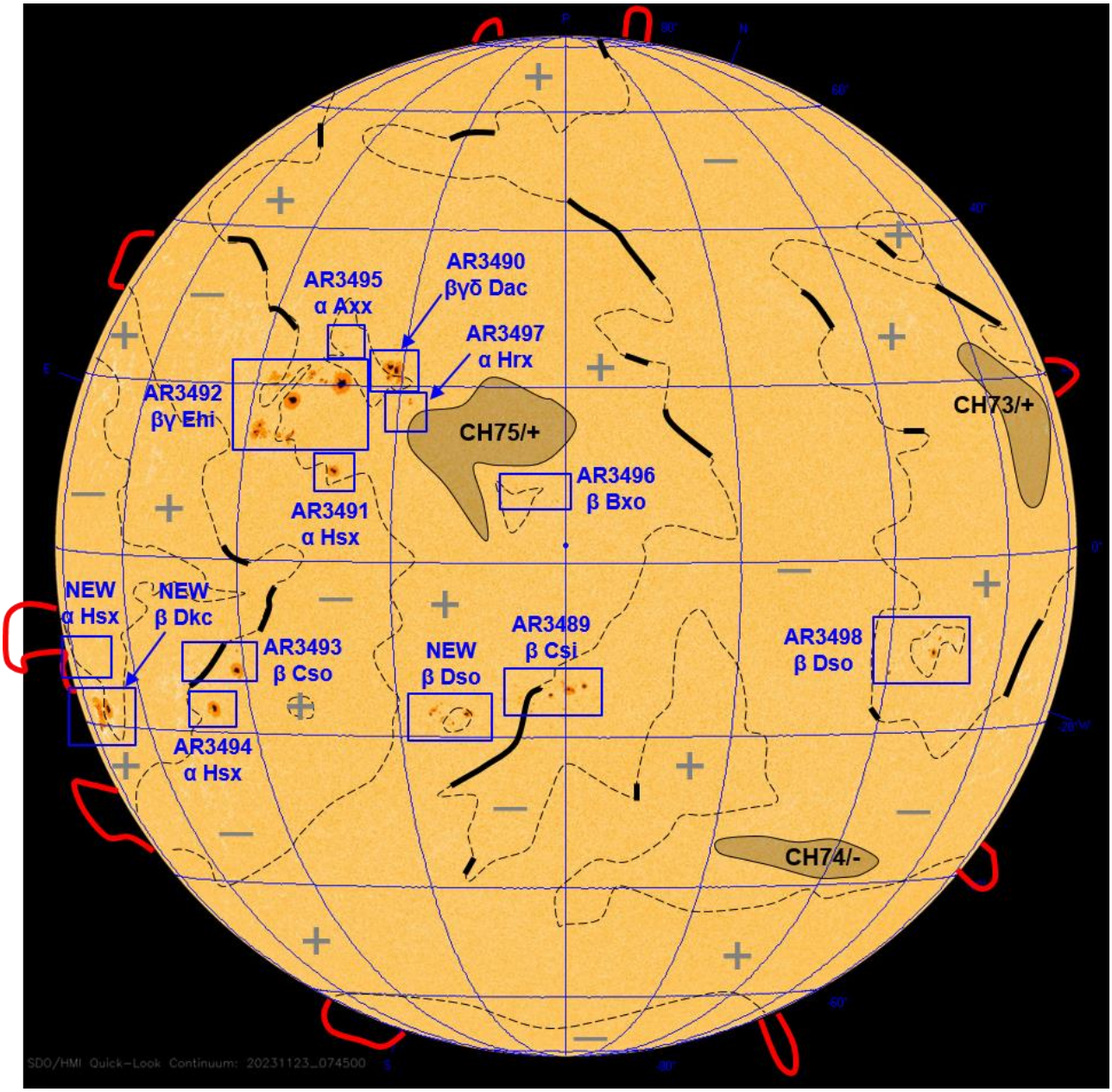
Figure 1. Solar Analysis Valid 23/0745 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

Two Earth-directed CMEs feature in the forecast. The first is from a filament eruption in the southeastern quadrant early on 22 Nov. Analysis and modelling of this feature suggests that the periphery of this feature is likely to affect Earth either late on day 2 (24 Nov), or more likely early day 3 (25 Nov). A second, partial halo CME is evident in LASCO and STEREO imagery from 22/2100 UTC onwards, directed mainly southwards. A coronal dimming spanning several hours is apparent starting around 22/1930 UTC in the vicinity of AR3489. This is also accompanied by two flare ribbons, indicative of post-eruptive magnetic reconnections in the Sun's corona following a filament eruption. Confidence is moderate for a CME arrival at Earth from this around 26/0000 UTC.

Earth remains connected to the waning high speed stream of coronal hole CH73/+, with slightly elevated solar winds initially, but on a decreasing trend and likely returning to slow-ambient levels within the next couple of days. The next HSS enhancement is anticipated from CH75/+ later on day 3 (25 Nov) or more likely day 4 (26 Nov). On the previous rotation, this coronal hole was a much larger and darker feature than it appears currently on coronagraph imagery, with speeds reaching 570 km/s and a prolonged period of several days at elevated levels. Geomagnetic activity on the previous rotation was Kp 3-5. Therefore it is thought that similar if not a slightly muted version of events will take place upon the connection of the CH75/+ on this rotation. Speeds of up to 500-550 km/s are possible. The arrival of the HSS may coincide with the arrival of the late 22 Nov CME, so an enhancement may be initially masked by the effects of the latter.

Geomagnetic Activity will be mainly Quiet on day 1 and 2 (23 and 24 Nov), with a chance of isolated Unsettled intervals. Activity should then increase to Active to G1/Minor Storm levels with the arrival of the early 22 Nov CME. This is most likely to occur early on day 3 (25 Nov), but with a slight chance of occurring late day 2 (24 Nov). Activity may briefly ease to Unsettled, then increase once again to mainly Active to G1/Minor Storm levels later day 3 (25 Nov) into day 4 (26 Nov) given combined HSS and further expected CME influences.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	1	10	50	50
Strong	G3	No	1	1	5	5
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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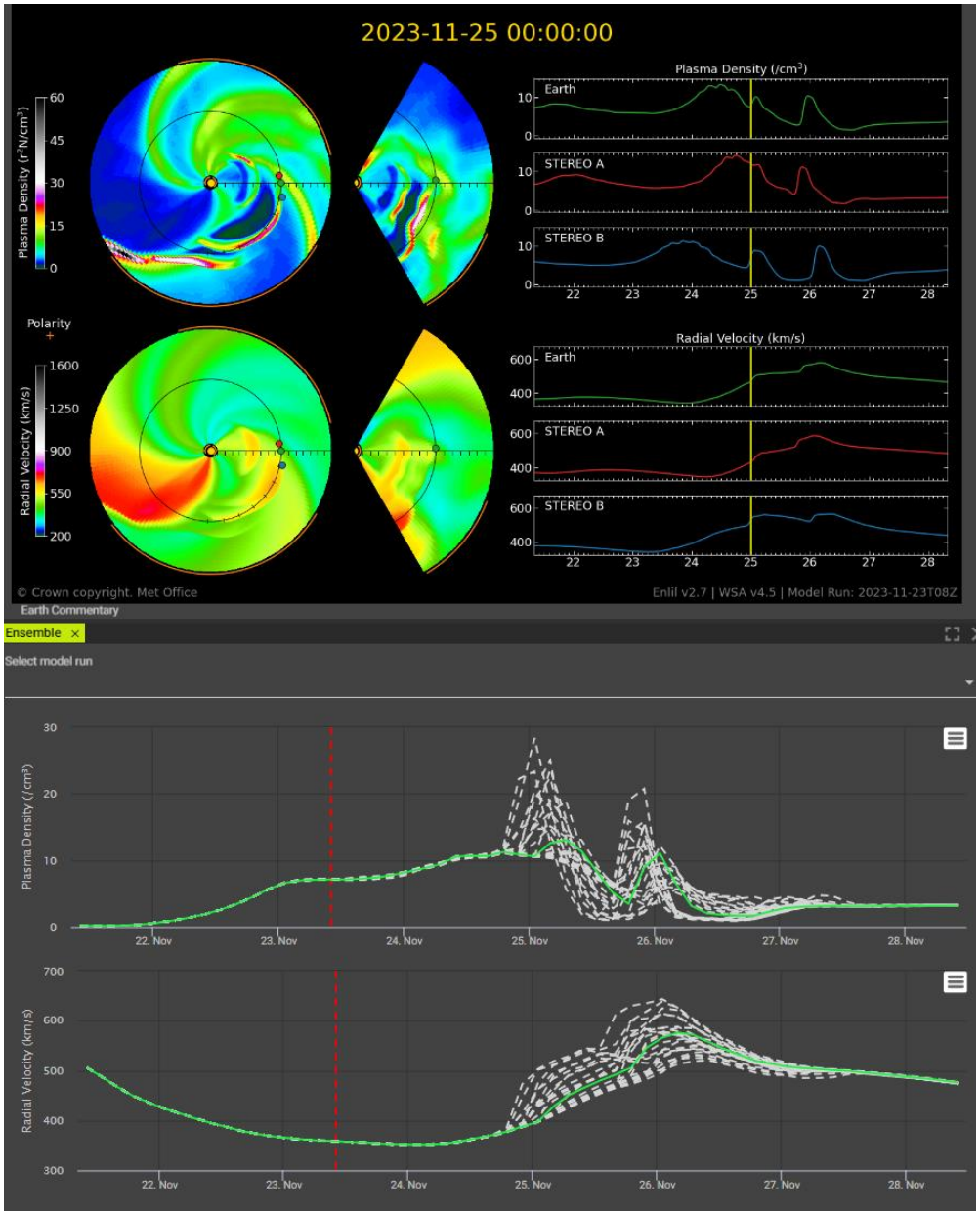
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
22/1241	Partial	Filament eruption	SE	760 km/s	25/0000 UTC	Nil
23/0535	Partial	Filament eruption	SE (near centre disc)	540 km/s	26/0000 UTC	Moderate confidence in arrival

Figure 2: Latest ENLIL output and Ensemble. Showing peripheral effect from early 22 Nov CME at Earth around 25/0000 UTC.



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Radio Blackouts - X-Ray Flares:

There are currently thirteen sunspot groups on the visible disc, the majority of which are located in the eastern solar hemisphere. The largest group is a new region in the far southeast. This is a compact, bipolar group, although the region is still significantly foreshortened in available imagery and may reveal more complexity as it rotates into clearer view.

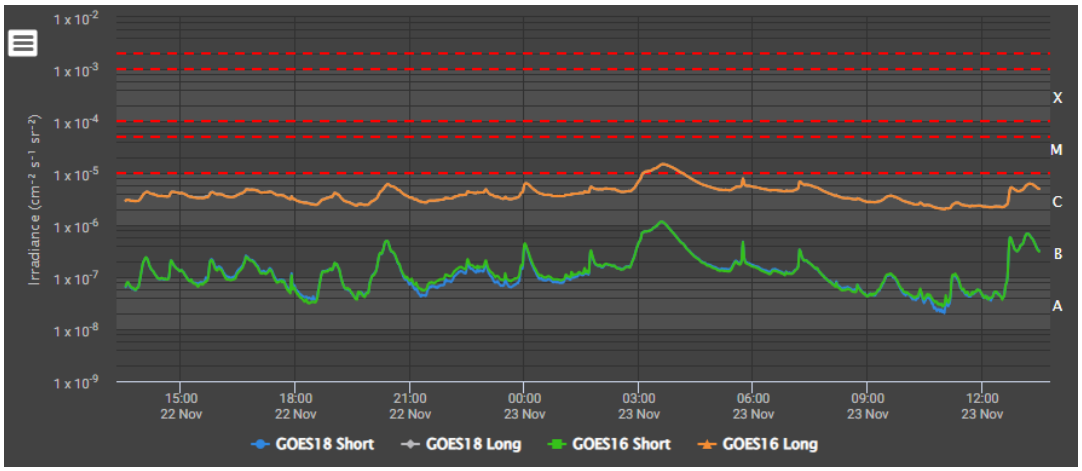
The northeast of the disc contains a cluster of sunspot groups that appear to be magnetically connected. AR3490 continues to show the presence of a small delta spot in the southern portion of the group. Meanwhile, the previous small delta spot in AR3492 appears to have decayed. These three regions make up the majority of the flare risk on the disc at present, with the remaining groups smaller and more magnetically simple at this time.

Frequent CME activity close to, or just beyond the northeast limb and SDO imagery suggests the presence of further active regions that are expected to rotate onto the visible disc in the coming days.

Moderate activity has been observed with a peak M1.4 flare at 23/0338 UTC. This is from an uncertain source given simultaneous flaring from a number of regions at the time, but is either from AR3492, AR3494 or a new region at, or just beyond the northeast limb. Moderate solar activity is expected to continue with further isolated M-class flares likely, and a slight chance of an isolated X-class flare.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	60	60	60	60
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: X-Ray Flux from GOES18 and GOES16



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Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is currently at Background levels.

There are several moderately-large, fairly complex regions in the eastern solar hemisphere, which result in an above background risk of a S1/Minor Solar Radiation Storm. This risk remains nominal until later in the period when these groups move into a more favourable location for connection with Earth, as they approach the western solar hemisphere.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

Electron flux levels are expected to continue to increase in the next couple of days as the current solar wind pressure from CH73/+ continues to ease. Flux levels should increase to vary between Moderate and diurnally High levels. A suppression of electron flux to mainly background levels is expected towards the end of the period due to combined CME and HSS influences.

Fluence levels are expected to remain below the 1e8 Active threshold initially, the risk of this being breached increases from day 2 (24 Nov) into day 3 (25 Nov), before decreasing again into day 4 (26 Nov).

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	40	40	10
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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Figure 4: Latest GOES16 Electron Flux (top) and MOSWOC REFM and recurrence (below)

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